# Plankton Distribution in Internal Waves in Massachusetts Bay


Jesús Pineda
MS 34 Biology Department
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
phone: (508) 289-2274 fax: (508) 457-2134 email: jpineda@whoi.edu

Scott Gallager
MS 35 Biology Department
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
phone: (508) 289-2783 fax: (508) 457-2134 email: sgallager@whoi.edu

Alberto Scotti
Dept. of Marine Sciences, Venable Hall, CB # 3300
University of North Carolina, Chapel Hill, 27599-3300
phone: (919) 962-9454 fax: (919) 962-1254 email: ascotti@unc.edu



Award Number: N00014 -01-1-0172
http://science.whoi.edu/labs/pinedalab/


## LONG-TERM GOALS

Our long-term goals are describing and understanding the mechanisms responsible for plankton accumulation and transport in large amplitude internal waves.

## OBJECTIVES

The general objective of our research is to observe the effects of tidally generated undular bores on near-surface plankton distribution. The particular objectives are (1) to determine the spatial scales of plankton distribution compared to the physical features before, during and after the internal tidal bores, and (2) to resolve whether plankton is concentrated by the physical characteristics of the bores. If there is a pattern in the plankton distribution associated to the bore, then another objective is (3) to determine whether plankton accumulation is dependent on plankton behavior, and whether, and to resolve whether taxa redistribute differentially in specific regions of the bore.

## APPROACH

We are using a combined observational and theoretical approach. Our observational program includes following internal bores as they propagate from Stellwagen bank to Scituate, in Massachusetts Bay. The bores are sampled with a shipboard Doppler current meter (velocity and backscatter) and a towed video plankton recorder (VPR). In addition to capturing images, the VPR records depth, conductivity, temperature, fluorescence, light attenuation and PAR (Photosynthetically Active Radiation). The program also includes observing the bores with moored instruments, including a moored video plankton observatory system ("AVPPO"), temperature moorings, and Doppler current meter profilers.

# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



| | | |
|---|---|---|
| 1. REPORT DATE<br>**29 SEP 2001** | 2. REPORT TYPE | 3. DATES COVERED<br>**00-00-2001 to 00-00-2001** |

| | |
|---|---|
| 4. TITLE AND SUBTITLE<br>**Plankton Distribution in Internal Waves in Massachusetts Bay** | 5a. CONTRACT NUMBER |
| | 5b. GRANT NUMBER |
| | 5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | 5d. PROJECT NUMBER |
| | 5e. TASK NUMBER |
| | 5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>**MS 34 Biology Department,,Woods Hole Oceanographic Institution,,Woods Hole,,MA,02543** | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | 10. SPONSOR/MONITOR’S ACRONYM(S) |
| | 11. SPONSOR/MONITOR’S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT<br>**unclassified** | b. ABSTRACT<br>**unclassified** | c. THIS PAGE<br>**unclassified** | **Same as Report (SAR)** | **7** | |

**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

Our observations on the particle accumulation by the bores will be contrasted with an internal bore model (Scotti and Beardsley, subm.) The bore model will also be used to guide our observational program. In general, Pineda and Gallager are responsible for the observational portion of the program, while Scotti is in charge of the theoretical aspect.

## WORK COMPLETED

The fieldwork component consists of two cruises, one in 2001 and another in 2002. The 2001 cruise sailing date, originally scheduled for September 10, was moved to September 12, due to an unforeseeable circumstance that prevented the Captain of the R/V Connecticut from being available on the planned date. Poor sea conditions forced us to return to port two days earlier than planned. Despite the reduced available time, we were nonetheless able to acquire a significant wealth of data. On our 2001 cruise we deployed five temperature moorings, located at 25 (1 mooring), 30 (1) and 45 (3) m water depth, and two Doppler current profilers at 25 and 45 m. The instruments acquired high frequency temperature and currents time series. We also obtained hourly profiles from seabed to surface of plankton, temperature, conductivity, fluorescence, light attenuation at 5 frequencies (AC-9), and up and down-welling irradiance with the AVPPO. We also sampled about 14 internal bore fronts as they propagated westward from Stellwagen bank, both during daytime and nighttime. Sampling was completed with the VPR (plankton, temperature, conductivity and depth) and with a shipboard 600 kHz Doppler current meter (backscatter, velocity.) The number of passes perpendicular to the wave crest ranged from 4 to 15.

On the theoretical side, we completed the physical part of the model and described the evolution of the internal undular bores in the area in a paper submitted to the Journal of Geophysical Research (Scotti and Beardsley, subm). We have also added a module to the model to study the advection of plankton by the internal tide.

## RESULTS

We have not had sufficient time to analyze the data; we plan to analyze it in the next few months. Our preliminary observations suggest that, on occasions, zones of high backscatter were associated to the internal bore depressions (Figure 1), and that these zones of high backscatter were present as the waves propagated. As has been observed before (LaFond, 1962), the waves were accompanied by surface slicks (Figure 2), and these slicks were often detected with radar (e.g. Haury et al., 1983). We sampled these zones of high backscatter simultaneously with the Video Plankton Recorder (VPR). Although a full analysis is required to quantify these results, real-time observations of plankton distributions associated with internal waves indicated taxon-specific associations within specific regions of the internal waves (IWs), and at certain times of the day.  A striking example of this was observed for Euphausiids (*Thyanessa rauchii* ?).  While Euphausiids were not observed associated with IWs during daylight hours, between the hours of 1900 and 0000, Euphausiids were found localized in the leading edges of the IW where vertical velocity vectors were downward.  Between the hours of 0200 and 0600, Euphausiids were found in very high abundance in the trailing edges of the IW where velocity vectors

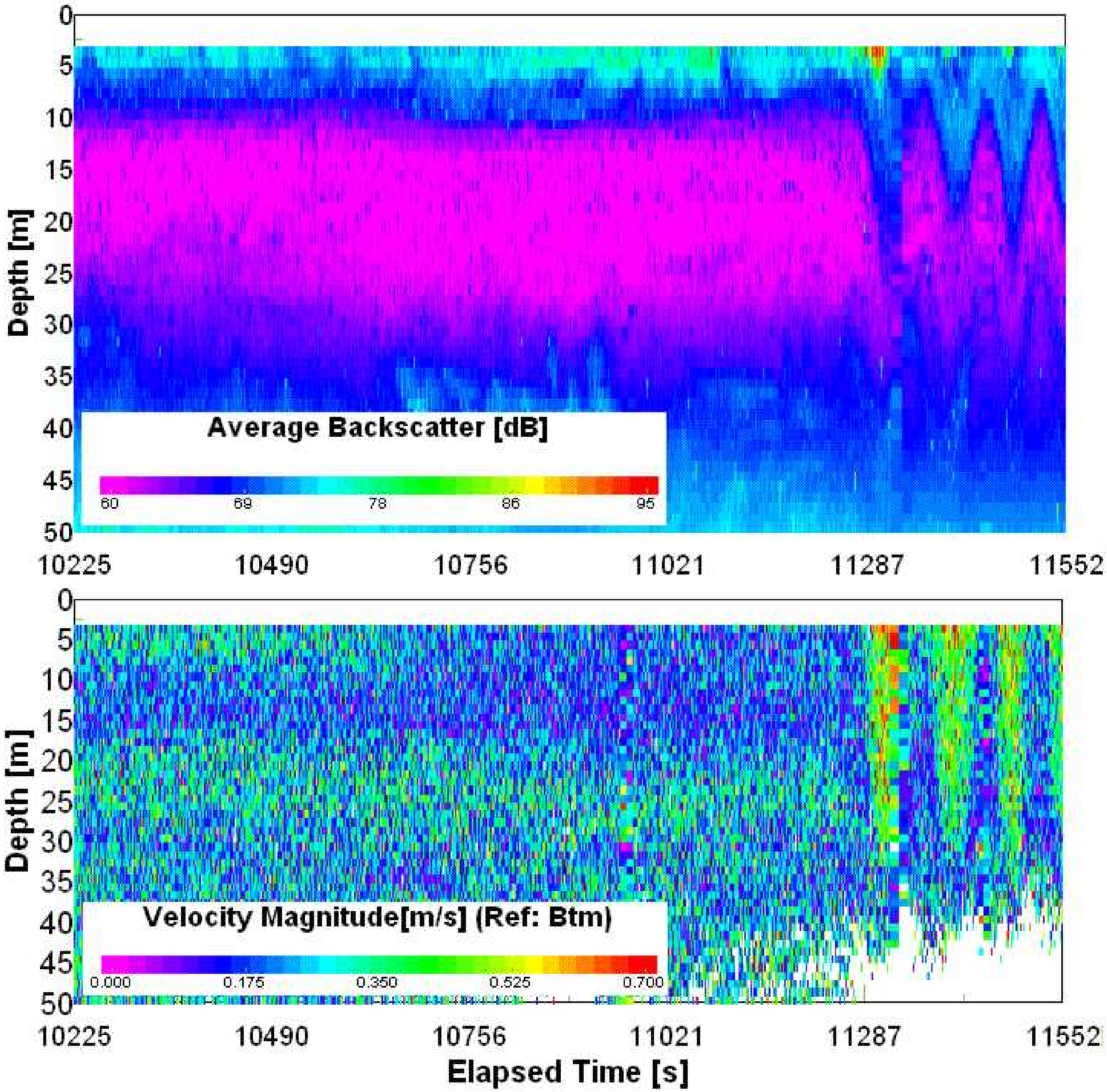


***Figure 1. Interpolated backscatter (top panel) and velocity magnitude (bottom panel) with depth (m) and time (s) obtained from the shipboard Doppler current meter. Bin size is 1 m. RV Connecticut steaming towards Stellwagen bank at about 3-4 knots. Patterns in backscatter and velocity magnitude reveal an internal bore followed by internal solitary waves.11552 s is about 9:11 EDT, 18 Sep 01. Note the zone of high backscatter in the first wave of depression.***
***[The top panel shows a three-layer, uniform backscatter pattern from time 10,225 s to time 11, 287 s. After 11,287 the backscatter reveal three waves of depression about 15 m in wave height. The velocity panel also reveals the three waves of depression, with larger magnitudes in the depressions than outside the depressions. Velocity magnitude is larger in the first wave of depression than in the second or third waves.]***

***Figure 2. Photo of a surface slick associated to the leading edge of the bore in Figure 1, observed from the bow of the RV Connecticut. The photo was taken 91 minutes after 09:11 EDT, 18 Sep 01. The boat was steaming onshore, in the direction of propagation of the wave. [A band of glossy water on the sea reveals the surface manifestation of the leading edge of the internal bore.]***

were upward. This suggests an interaction between vertical migration behavior and velocity structure in controlling location and patch dynamics of Euphausiids in IWs.

We also observed the evolution of bores with trailing high frequency internal waves, in ~80 m water, into bores with no trailing waves at ~30-40 m water. We have previously observed the occurrence of an internal tide in very shallow water (20-25 m). With our moored and towed observations, we will resolve whether the arrival of the bore that generates at Stellwagen Bank (Scotti and Beardsley, subm.) corresponds to any particular phase of the shallow internal tide.

The numerical model shows that the sloping bottom to the west of Stellwagen Basin, under the majority of the environmental conditions observed, acts as a low-pass filter for the internal bore. The high frequency train of solitary waves trailing the initial depression does not propagate beyond the 30-m isobath, but dissipates due to instabilities. However, the leading edge of the bore is able to move upshelf towards shallow waters (see Figure 3).

## IMPACT/IMPLICATIONS

Our research will shed light on the formation and persistence of zooplankton patchiness by internal bores and waves, and whether zooplankton behavior influences this pattern.

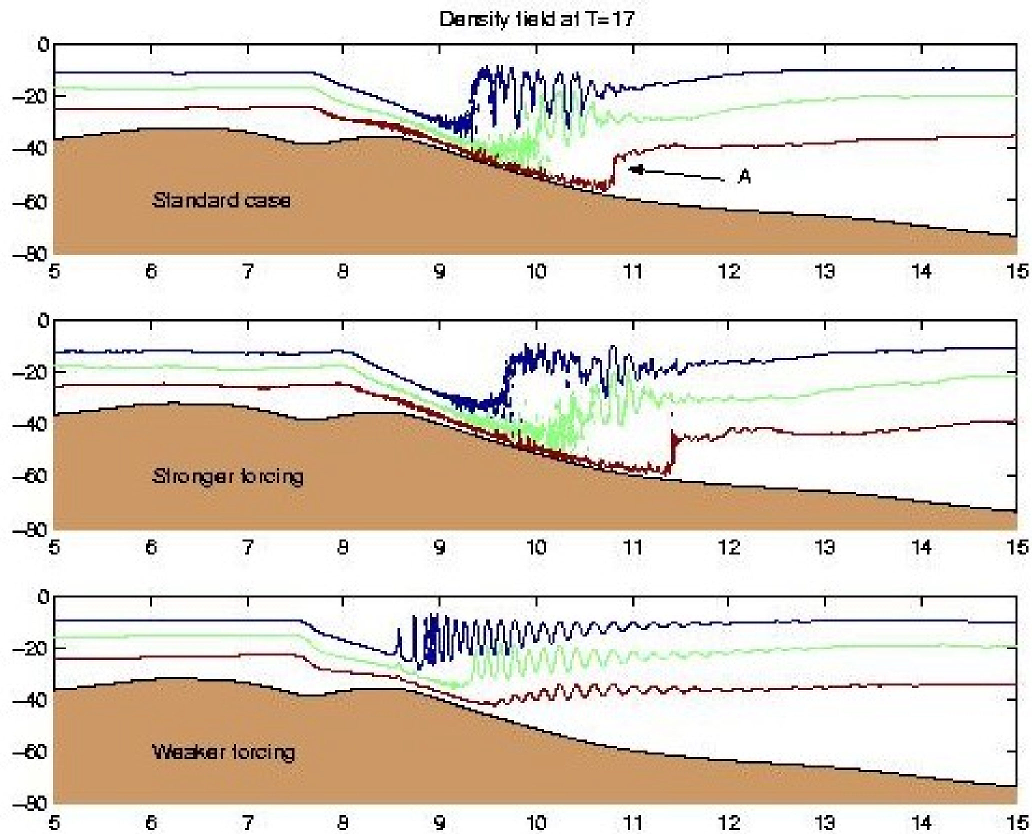


***Figure 3. The internal undular bore approaching the shallow area west of Stellwagen Basin. The time is 12 hours after low tide. Stellwagen Basin is to the right, Scituate to the left and shown are lines of constant density. Depth are expressed in meters, horizontal distances are in km. From top to bottom conditions refer to mean tide, spring tide and neap tide. The high frequencies waves become unstable and collapse. On the shelf a wave of depression propagates.***
***[The top panel shows the profile of the bottom, shaded, and three lines representing surfaces of constant density. The bottom depth decreases from right to left. The high frequency waves do not propagate past the 40-m isobath. Middle panel: same as top, but during spring tide. Bottom panel: same as top, but during neap tide.]***

## TRANSITIONS

None

## RELATED PROJECTS

This project is a new start. Scotti's modeling paper is related to a USGS project on internal waves in Massachusetts Bay.

## REFERENCES

Haury, L.R., Wiebe, P.H., Orr, M.H., Briscoe, M.G., 1983. Tidally generated high-frequency wave packets and their effect on plankton in Massachusetts Bay. Journal of Marine Research 41, 65-112.

LaFond, E.C., 1962. Internal waves. In: Hill, M.N. (Ed.), The Sea, Vol. 1, John Wiley and Sons, New York, pp. 731-751.

Scotti A. and R. Beardsley, subm. Large internal waves in Massachusetts Bay. Part 1: Modeling generation, propagation and shoaling. Submitted to JGR.

## PUBLICATIONS

Scotti A. and R. Beardsley, subm. Large internal waves in Massachusetts Bay. Part 1: Modeling generation, propagation and shoaling. Submitted to JGR.